Photosynthetic induction responses of *Pinus koraiensis* seedlings grown in different light environments

ZHOU Yong-bin[1], YIN You[1], LIU Xing-shuang[2], WANG Qing-li[3]
[1] *Shenyang Agricultural University, Shenyang 110161, P. R. China*
[2] *China University of Mining & Technology, Beijing 100083, P. R. China*
[3] *Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110015, P. R. China*

Abstract: The time processes of photosynthetic induction responses to various irradiances in Korean pine (*Pinus koraiensis*) seedlings grown in open-light environments and in understory of forest were studied in an area near the Research Station of Changbai Mountain Forest Ecosystems, Jilin Province, China from July 15 to August 5, 1997. The results showed that at 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ photosynthetic photon flux density (PPFD) and 500 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPFD, the induction time for the photosynthetic rates of understory-grown seedlings to reach 50% and 90% steady-state net photosynthetic rates was longer than that of the open-grown seedlings. The induction responses of open-growth seedlings at 500 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPFD were slower than those at 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPFD, but it was the very reverse for understory-growth seedlings, which indicates that the photosynthetic induction times of Korean pine seedlings grown in the understory depended on the sunfleck intensity.

Key words: *Pinus koraiensis* seedlings; Photosynthetic induction responses; Natural light
CLC number: S718.5; S791.247 **Document code:** B **Article ID:** 1007-662X(2004)03-0246-03

Introduction

Korean pine (*Pinus koraiensis*) is considered moderately shade-tolerant tree species and is capable of regenerating under broadleaved forest. In general, leaves of shade-acclimated plants have a lower dark respiration rate and a lower light-saturated photosynthetic rate on a leaf area basis. Simulations of photosynthetically dynamic responses in controlled laboratory conditions indicated that shade plants have higher light-use efficiency during sunflecks than sun plants due to faster photosynthetic induction responses (Pons *et al.* 1992; Tang *et al.* 1994). However in the past years, photosynthetic acclimation of conifers to sun and shade conditions has not been well studied (Stenberg *et al.* 1995). Furthermore, few researchers studied light acclimation in relation to photosynthetic behavior under natural light conditions (Young and Smith 1980; Chazdon and Kaufmann 1993), and it is little known about the dynamic responses of net photosynthesis related to light acclimation under field conditions. The objective of this study was to examine the time processes of photosynthetic induction responses to various irradiances in Korean pine seedlings grown in open-light environments and the forest understory.

Biograph: ZHOU Yong-bin (1970-), female, associate professor of Shenyang Agricultural University, Shenyang 110161, P. R. China. Email: yyzyb@163.com
Received date: 2004-06-13
Responsible editor: Song Funan

Materials and methods

Study site and seedlings

Study site is located near the Research Station of Changbai Mountain Forest Ecosystems (42°24'N, 128°28'E). The mean annual precipitation is 760 mm, mean annual temperature is 0.9-4.0°C, with mean temperature of two months > 10°C, and soil type is the mountain dark brown forest soil.

Three-year-old Korean pine seedlings were obtained from a local nursery and planted in the open field and understory. The stand composition was *Butula platyphylla*, *Tilia amurensis*, *Rraxinus mandshurrica* and *Quercus mongolica* etc.. The mean height of the stand was 7 m, and mean age of the canopy trees was 10. After two years, 10 seedlings (half from the forest understory and the other from the clearcut) were randomly chosen for measuring light and gas exchange. Only the uppermost lateral branches with one-year-old needles were selected for the measurement of gas exchange.

Light measurements

The light sources consisted of natural light in field and the low light which was made by covering white gauze on cuvette of photosynthesis system to reduce natural light. Light measurements were conducted under clear sky conditions from July 15 to August 5, 1997.

Gas exchange measurements

Gas exchange measurements were conducted on five randomly chosen seedlings by photosynthesis system

(CID-301PS). An air bag was used to take fresh air outside to reduce the variation of CO_2 concentration. Photosynthetic induction responses at 200 and 500 μmol·m^{-2}·s^{-1} were taken after a 10-minute sample pretreatment at 50 μmol·m^{-2}·s^{-1} photosynthetic photon flux density (PPFD).

Results

Light availability

A mean PPFD at the branches of the open-grown seedlings was 708.2 μmol·m^{-2}·h^{-1}, whereas a PPFD at branches of the understory-grown seedlings was 172.6 μmol·m^{-2}·h^{-1}. In the understory, the continuance of a PPFD above 500 μmol·m^{-2}·h^{-1} was 130 min, while the continuance of a PPFD above 200 μmol·m^{-2}·h^{-1} was 280 min. The representative daily courses of PPFD in the forest understory and in the open were shown in Fig.1.

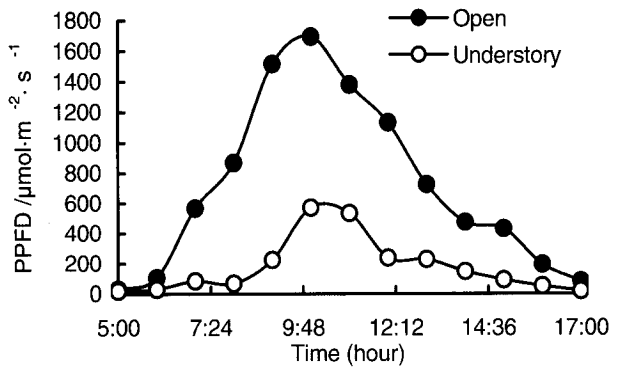

Fig. 1 Light availability for a seedling branch in the forest understory and open

Dynamic photosynthetic induction response

The increases of net photosynthetic rate for open-grown seedlings were more than those of understory-grown seedlings at both PPFD of 500 and 200 μmol·m^{-2}·s^{-1}. The understory-grown seedlings showed a slower induction response compared to the open-grown seedlings (Figs. 2 and 3).

When 500 μmol·m^{-2}·s^{-1} PPFD was applied, the mean time required to reach 50% and 90% of the steady state photosynthetic rate were 75 s and 199 s for the understory-grown seedlings and 59 s and 128 s for the open-grown seedlings, respectively. When 200 μmol·m^{-2}·s^{-1} PPFD was applied, the mean time required to reach the 50% and 90% induction state were 92 s and 234 s for understory-grown seedlings and 32 s and 50 s for the open-grown seedlings, respectively.

After a 10-minute sample pretreatment at 50 μmol·m^{-2}·h^{-1} PPFD, the induction time for the photosynthetic rates of open-grown seedlings to reach 50% and 90% steady-state net photosynthetic rates was shorter than that of understory-grown seedlings at 200 or 500 μmol·m^{-2}·s^{-1} PPFD. The induction responses of open-grown seedlings at 500 μmol·m^{-2}·h^{-1} PPFD were slower than those at 200 μmol·m^{-2}·h^{-1} PPFD. But the induction responses of understory-grown seedlings at 500 μmol·m^{-2}·s^{-1} PPFD was much more rapidly than those at 200 μmol·m^{-2}·s^{-1} PPFD. These results showed that the photosynthetic induction time of Korean pine seedlings grown in the understory depended on the sunfleck intensity.

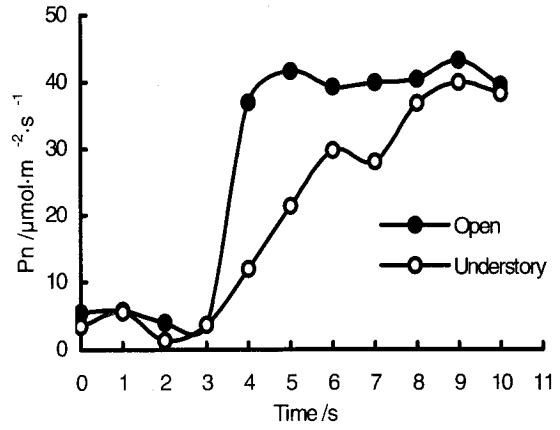

Fig. 2 Induction response of *Pinus koraiensis* to a step change from a 10 min PPFD of 50 μmol·m^{-2}·s^{-1} to 200 μmol·m^{-2}·s^{-1}
(Each point is the mean of one measurement from each of five different seedlings)

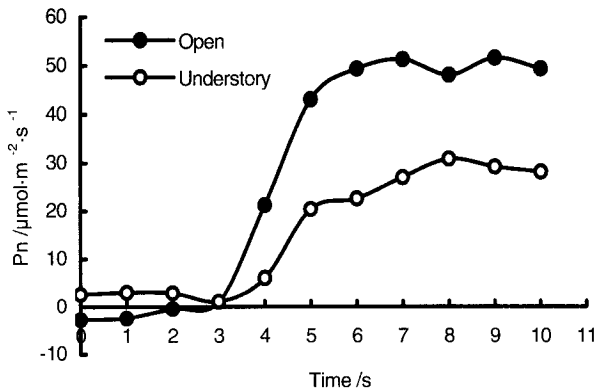

Fig. 3 Induction response of *Pinus koraiensis* to a step change from a 10 min PPFD of 50 μmol·m^{-2}·s^{-1} to 500 μmol·m^{-2}·s^{-1}
(Each point is the mean of one measurement from each of five different seedlings)

Discussion

The induction responses to PPFD changes were much more rapidly on the understory-grown branches than those in the open-grown branches. This result was consistent with studies in a tropical forest (Kuppers's *et al.* 1996) and in controlled environments on some broadleaf plants (Pons

and Pearcy 1992; Tang *et al.* 1994). Our study found that induction responses of Korean pine seedlings grown on the open field were much more rapidly than that of the seedlings grown in understory when 200 and 500 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPFDs were applied.

The time requirement to reach full induction varies from one species to another (Chazdon 1988) and mainly depends on (1) the light intensity and continuance of the sample pretreatment (Pons *et al.* 1992); (2) other ecological factors such as water status and so on. In this study, we also found that the time to reach the induction state depends on the sunfleck intensity of PPFD for induction.

References

Chazdon, R.L. 1988. Sunflecks and their importance to forest understory plants [J]. Adv. Ecol. Res., **18**: 1-63.

Chazdon, R.L. and Pearcy, R.W. 1991. The importance of sunflecks for forest understory plants [J]. Bioscience, **41**: 760-766.

Kuppers, M., Timm, H., Orth, K. *et al.* 1996. Effects of light environment and succession status on lightflecks use by understory trees of temperate and tropical forests [J]. Tree Physiol., **16**: 69-80.

Pons, T.L., and Pearcy, R.W. 1992. Photosynthesis in flashing light in soybean leaves grown in different conditions. Ⅱ. Efficiency of utilization of lightflecks [J]. Plant, Cell and Environ., **15**: 577-584.

Stenberg, P., Delucia, E.H., Schoetle, A.W. and Smolander, H. 1995. Photosynthetic light capture and processing from cell to canopy [C]. In: Smith, W.K., and Hinckley, T.M. (eds.) Resource Physiology of Conifers: Acquisition, Allocation, and Utilization. New Pork: Academic Press, p3-38.

Tang, Y., Hiroshi, K., Mitsumasa, S., and Izumi, W. 1994. Characteristics of transient photosynthesis in *Quercus serrata* seedlings grown under lightfleck and constant light regimes [J]. Oecologia, **100**: 463-469.